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Optimal Rock Properties, Natural and Modified, for Civil Engineering Applications

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Abstract: Rock masses are inherently heterogeneous, consisting of rock blocks separated by discontinuities like joints, faults, and bedding planes. This heterogeneity poses significant challenges for rock engineering and construction projects. The rock and rock aggregates exhibit varying mechanical properties influenced by their mineral composition, texture and structural features. Igneous rocks tend to be strongest due to interlocking mineral grains, while sedimentary rocks are weaker with higher anisotropy from sedimentary structures. Metamorphic rocks can be strong but may display anisotropy from their preferred mineral orientation. Certain minerals like mica, chlorite, and swelling clays can adversely impact rock strength and stability. Weathering and alteration processes further degrade rock properties through mechanical disintegration and mineral decomposition. Characterizing discontinuity properties like spacing, roughness, and infill is crucial, as discontinuities often control the rock mass behaviours more than intact rock strength. Comprehensive site investigations considering around 28 parameters related to rock materials, discontinuities, and hydrogeological conditions are essential for assessing the suitability of rock masses for construction purposes and ensuring safe engineering designs.
Key words: Optimal rock properties,civil engineering application,Natural and modified

Introduction

A rock mass is heterogeneous, consisting of rock blocks and fragments separated by discontinuities. This leads to interdependent alterations in the material properties. The characteristics of a rock mass include the shape and dimensions of the rock blocks/fragments, their texture within the mass, and the joint characteristics. The complex structure and inherent heterogeneities of rock masses present significant challenges for rock engineering and construction projects. Effective design and construction quality depend heavily on thoroughly understanding the geological setting and rock types at the project site.

Types of rock materials

There are three main types of rocks found in the Earth's crust - igneous, sedimentary, and metamorphic rocks. Igneous Rocks are formed from molten magma, these are primary rocks, tend to be massive and of high strength. Characteristic feature densely interlocking minerals resulting in uniform mechanical properties. Sedimentary Rocks are formed from fragments of disintegrated igneous rocks that are weathered, eroded, transported and deposited. They exhibit significant variation in strength and properties. Minerals are softer and bound by an inter-granular matrix, making them weaker than igneous rocks often contain bedding, lamination and sedimentary structures leading to anisotropy in physical properties such as shale, sandstone (strongly anisotropic), mudstones (unstable, susceptible to slaking and swelling). Metamorphic Rocks are formed by recrystallization of existing rocks under high temperature and pressure conditions. These rocks display a wide range of structures, compositions and properties due to metamorphism, often produce hard minerals and high intact rock strength and preferred orientation of sheet minerals can cause directional differences in mechanical properties like micaceous and chlorite schists (highly anisotropic) (Figs. 1&2).

Influence of minerals

Certain elastic and anisotropic minerals like mica, chlorite, amphiboles and pyroxenes can significantly influence the mechanical p6roperties of rocks. In sedimentary and regionally metamorphic rocks, these minerals tend to align parallel creating planes of weakness along their layers. Continuous layers of Minerals like mica and chlorite increase the anisotropic nature. Minerals like serpentine, talc and graphite (sheet minerals) reduce rock strength by enabling sliding along cleavage surfaces. Quartz mineral (hardness 7) that can adversely affect drill bits/cutters due to its sharp/obtuse angled edges in percussion drilling and tunnel boring. Rounded quartz grains have less impact.

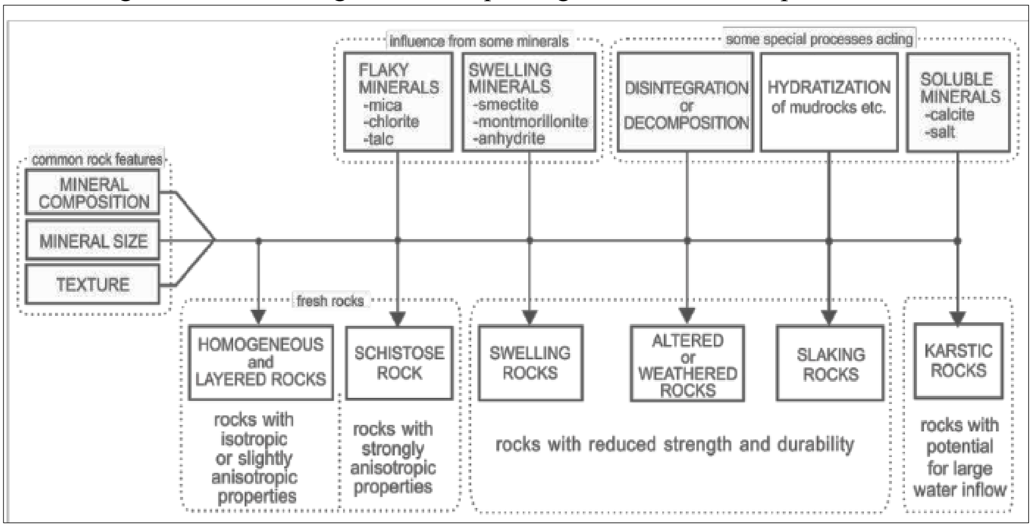


Fig.1. Influence on minerals and its effects on strength of the rocks (Palmstrom,2017)

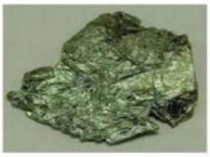
Flaky minerals	Swelling minerals	Isotropic minerals	Anisotropic minerals
Mica 	Smectite 	Garnet 	Orthoclase feldspar 
Chlorite 	montmorillonite 	Spinel 	Calcite 
Talc 	Anhydrite 	Fluorite 	Tourmaline 

Fig 2. Susceptible minerals for alteration.

Swelling minerals from the smectite (montmorillonite) group pose problems due to high swelling pressures caused by moisture changes. They expand, exhibit low shear strength, leading to rock falls/slides in underground openings. Rocks may swell, oxidize, disintegrate or weather due to humidity/temperature changes after excavation.

Effect of alteration and weathering

Weathering and alteration processes reduce the strength and deformation capacity of rock material, changing its mechanical properties and engineering characteristics. Near the surface, rocks undergo physical, chemical and biological weathering/alteration leading to mechanical disintegration causing loss of coherence, development of joints, fractures, disrupted grain boundaries, fracturing/cleavage of individual mineral grains. The chemical alteration changing mineral composition, rock discoloration, decomposition of complex silicate minerals into clays, Leaching of minerals like calcite, anhydrite, salt formation of sheet joints in upper weathering zone.

Mechanical properties of rocks
Rocks with varying mineral composition, porosity, cementation, consolidation, texture and structural anisotropy exhibit different strength and deformation properties. Petrological data is essential to predict mechanical rock performance. Using specific rock type names provides relative indications of inherent properties.

Discontinuities in rocks
Discontinuities like faults, joints, intrusions, bedding planes, tension cracks, roughness, bedding contacts, weathering characteristics, gouges and groundwater susceptibility disrupt the homogeneity of a rock mass. Their impact varies based on structure, composition and type. Large discontinuities significantly affect underground opening stability and excavation, requiring special attention and investigations. Joints are present in all exposed hard rocks. Analysing them is challenging due to numerous characteristics like length, continuity, roughness, wall strength, planarity, alteration, filling, water flow, all influencing shear strength. Decreasing joint spacing increases rock wall interlocking and roughness affecting shear strength. Methods to measure joint density/spacing on surfaces or cores include assessing block size, textures, composition, and joint structures using Rock Quality Designation (RQD).

Rock mass characterization
Involves selecting significant parameters for a particular design/construction type. *In-situ* testing shows variations in mechanical behaviour across locations. A rock mass engineering properties depend more on its discontinuities than rock strength itself. Rock texture often governs strength. Understanding discontinuity geometric parameter variability is crucial for discontinuous rock mass stability issues. Reliable investigations into rock nature are essential construction requirements. Rock properties like compressive strength, hardness, anisotropy are used to assess drillability, crushability, suitability as concrete/asphalt aggregates, feasibility of full-face boring machines. Overall, 28 parameters related to rock material, discontinuities and hydrogeology may influence a rock mass' strength, deformability, permeability or stability behaviour.

Conclusions
In summary, understanding the inherent properties of different rock types, the effects of alteration/weathering, and detailed characterization of discontinuities are vital for evaluating the suitability of rock masses as construction materials and ensuring safe, stable, and economical rock engineering and construction practices.

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